

drizzle. The densest fogs are those in which the droplets of moisture are exceedingly tiny.

Fog in the northeastern quarter of the country generally may be described as (1) valley, (2) mountain, (3) ocean, (4) snow or rain. Fog can frequently be ascribed to two or more of these conditions; often their origin and cause are more or less obscure because it is difficult to secure full information as to their exact extent.

Valley fogs are essentially phenomena due to radiation and air drainage. Their formation is best watched by assuming that they will form, unless inimical conditions are present, in any broad valley during the night hours. The longer the night the greater the chance and extent of fog. There is little chance for fog if at sunset the temperature and dew point have a difference of 15° F. or more. Such fogs may fill the valleys by sunrise but usually "burn off" under rising temperatures during the first four hours of daylight. If, however, a sheet of high clouds comes in over these fogs their dispersion is greatly delayed.

Mountain fogs are strictly low cloud ceilings which envelop the higher points of the terrain. When the ceiling lifts the fog observed as such by an observer on the mountain top disappears.

Ocean fogs occur on the coastal plain of the Atlantic seaboard and are frequenters of the southern and western sections of HIGHS which are located a short distance to the east of the Canadian and New England coasts. From local indications it is practicable to predict their occurrence by closely observing the wind direction and velocity and the temperature at stations on the coast. A desultory south or southeast wind whose temperature is normal or below in the daytime will often suddenly turn back to a chilly east or northeast light breeze at night and fog will attend this shift of wind. Once formed such fogs are persistent and depend for their dispersion on a greatly altered pressure distribution, as it often happens that an incoming Low from the west will draw southerly to southwesterly winds up over the top of the fog for several hours before it gradually wears away the upper surface of the fog and draws out the colder inversive temperature layer of foggy air.

Fog in the vicinity of the Great Lakes is less common but similar in production to the ocean fogs. It is easily formed when precipitation has occurred or is still occurring with winds which are light to calm, if the temperature of the water surfaces is above that of the land. In winter the lakes have ice and their temperature is therefore near freezing. At other seasons lake temperatures are normally colder than land temperatures, and therefore, the fog is slow to develop over the land.

Any widespread fog is the result of a widespread condition, hence slower to disperse than a local or limited one. On the other hand, during the evening or the period of development all fogs are likely to start as local phenomena and if the night is long the merging of several local fogs may result by sunrise. A winter fog usually is less mobile and more likely to stagnate than a summer fog, while the spring fogs are involved in cold surfaces and are often abnormally stagnant.

"Snow" fogs result when warm, moist air blows over snow-covered terrain. The reduction of the air temperature by the snow is the cause. If the snow is substantial enough to last under the influence of the warm air fog will form. The farther to the windward the snow cover exists, the more likely is the fog to form at any specific point.

Rain in summer sometimes chills and wets the ground in a region to the extent that the lower strata of air are abnormally chilled while blowing very slowly over this

region. Fog will result if the chilling is great or the moisture content of the air is high. Such fogs are usually transient, although if they occur in the early evening they may merge into valley fogs. Rising wind will disperse them quickly.

SOUTHEASTERN STATES

By JOHN A. RILEY

[Weather Bureau Airport, Atlanta, Ga.]

The southeastern portion of the United States lies south of the most frequented storm tracks. The storms that cause heavy rainfall in this region are southwestern lows, including those that form in the Gulf of Mexico and those from the northwest that move far to the south before recurving. A considerable portion of the West Indian hurricanes pass inland on the Gulf coast or move up the Atlantic coast, causing widespread cloudiness, high winds, and heavy precipitation. But these storms are confined mostly to late summer and autumn and, in most years, are not frequent enough seriously to affect flying.

This comparative freedom from storms, however, does not mean that the flying weather of the Southeast is better than that of other sections. In fact the topography of the region and the proximity of an abundant supply of heat and moisture from the Gulf of Mexico and the Atlantic combine to produce weather conditions that seriously interfere with flying at frequent intervals during a considerable part of the year.

The Appalachians, forming a high backbone between the Mississippi River and the Atlantic, are a decided topographic factor in determining ceiling and visibility. Even in fair weather a perpetual haze hangs over these mountains, as such names as Great Smoky and Blue Ridge suggest. This haze is sometimes so stratified as to resemble clouds, and the upper surface at 4,000 to 6,000 feet (1,200 to 1,800 meters) often furnishes a distinct horizon from above.

A notable instance of the effect of moist winds blowing across mountain ranges is found in northern Georgia and southwestern North Carolina. On the southern slope the rainfall increases from 50 and 55 inches (130 to 140 centimeters) over the lower slopes to 60 and even 80 inches (150 to 200 centimeters) a year on the higher slopes, while in the valleys beyond the rainfall drops to less than 40 inches (100 centimeters). The ridges of the southern Appalachians in Tennessee, Alabama, and Georgia seem to stretch out like fingers to grapple with the prevailing winds and squeeze out the moisture to form clouds, fog, and rainfall.

The Gulf of Mexico, as R. DeC. Ward points out,¹ is an important control of the climates east of the Rocky Mountains. It is a very warm body of water, and the most important source of moisture for the heavy rainfall of the Southeast.

The Atlantic probably exercises an equally important control over flying conditions on the Atlantic seaboard and as far west as the Blue Ridge Mountains, easterly winds being definitely associated with low stratus clouds which are the most serious handicap to flying in this region. At Atlanta, for instance, the percentage of rain during the time the wind is northeast is five times as high as with northwest winds. Taking this value as unity for northeast winds the relative probability of rain for the other directions is as follows: North, 0.31; northeast, 1; east, 0.56; southeast, 0.59; south, 0.32; southwest, 0.61; west, 0.26; northwest, 0.17.²

¹ The climates of the United States.

² Cf. The rain-bearing winds at Atlanta, Ga., by C. F. Von Herrmann, Monthly Weather Review, Nov., 1925.

High-pressure areas on the middle or north Atlantic coast constitute the controlling factor in the formation of low clouds over the east slope. A slow-moving HIGH over New England, with an extension southwestward, and a moderate LOW on the Gulf coast or in the Mississippi Valley may be depended upon to produce a more or less extended period of low overcast.

The normal clockwise movement of the winds around the northeastern HIGH causes the easterly surface winds to be overrun by moist southerly winds from the Gulf. The winds in this system, both at the surface and aloft, have a high vapor content and the relative humidity increases with falling temperature as the surface winds climb the slope from sea level, across the Piedmont Belt at 1,000 feet (300 meters) to 2,000 feet (600 meters) or more at the mountains. At the same time the southerly winds aloft are near the saturation point which may be passed as convergence causes further ascent and cooling.

The first clouds may form either near the ground or in the overrunning southerly winds, depending on the vertical distribution of temperature and humidity. When fully developed there may be four or five distinct cloud strata. Weather maps of February 7, 13, and 22, 1928, illustrate these conditions. Typical conditions occurred on September 13, 1929, when Air Mail Pilot Sid Molloy lost his life at Atlanta while attempting to fly underneath a very low overcast which touched the ground in places.

F. T. Cole, of the Weather Bureau Aerological Station at Due West, S. C., says that the most potent cause of low clouds from mid-November to mid-May is a strong LOW to the southwest with a good gradient. Lows that move to the north and east from the Gulf coast—Brownsville to Pensacola—bring low clouds about 12 hours ahead of the rain, and the rain is always accompanied by low clouds. But before low ceiling becomes a certainty the pressure must begin to fall; that is, the LOW must really begin to move. Lows that come out of the east Gulf, he says, will bring low clouds at all seasons of the year if of any intensity. Lows that pass up the Atlantic coast in the autumn, October 1 to December 15, frequently bring threatening weather that apparently moves in from the east. If the movement of the LOW is blocked low ceiling with easterly winds may prevail for several days, but the clouds will be broken and the rainfall light.

Cole finds that temperature and humidity are of little forecast value but that winds aloft are at times indicative of low clouds on the following day. A gradual change from east-southeast to south-southwest in a layer some 3,000 feet (900 meters) deep is almost a sure precursor of low ceiling and rain, but this does not hold true when the wind shifts abruptly.

A low overcast may occur when pressure gradients are insufficient to cause rainfall. Such conditions may prevail for several consecutive days and the weather then has a more or less regular diurnal sequence. Low clouds drift in between midnight and 3 a. m. or 4 a. m. and lift about 9 a. m. or 10 a. m. the following morning.

Moderately sharp temperature contrasts on the Jacksonville-Atlanta airway are often indicative of bad weather; they usually occur along the southeast margin of an incoming HIGH. The low temperature within the high-pressure area and the high temperature to the south and east produce the well-known displacement of the center of low pressure toward the colder region, usually toward the northwest.³ As a result of this displacement

the northerly surface winds are overrun by south and southwest winds, causing low clouds, rain, and poor visibility.

The period covered by the air-mail service in the southeast is too short to show the seasonal trends of flying weather. Ceiling measurements covering nine years at Due West, S. C., have been tabulated for this study by F. T. Cole. These figures show a steady decrease in frequency of low clouds from December to July, with a slight rise in August and September due to the hurricane season which reaches its height during this period, and then a drop to a minimum in October essentially the same as in July.

Low clouds are rather common on summer mornings but they seldom last all day; the duration of low clouds is much greater in winter. Considerable variation in frequency of bad flying conditions occurs from year to year in every month. For instance, February, 1929, was probably the worst month since regular schedules began in this district whereas February, 1930, was for the most part unusually fine.

Thunderstorms are the principal handicap to flying in summer; there are few warm days in summer when mail pilots in this territory do not report seeing one or more, and many times it is necessary to dodge one after another. It is not generally practicable to fly above them, but the pilot tries to pick out what appears to be the lightest or least active part of the storm.

Thunderstorms not only seriously reduce the ceiling and visibility while in progress, but the path of an afternoon or night thunderstorm is likely to be marked the following morning by ground fogs. On such nights temperature and dew-point readings are highly significant and are closely watched by experienced pilots. These fogs form within an hour or two after midnight and burn off soon after sunrise. Most of the inland fogs of summer are formed in this way; they are much more frequent than past records would indicate, for by 8 a. m., the time of the regular morning observation, summer fogs are entirely dissipated.

Over most of the Southeast, except lower Florida, dense fogs occur on an average of 15 to 20 or more days a year; the greatest frequency is in the valleys of the middle and southern Appalachians, diminishing toward the west as well as toward the Atlantic and Gulf coasts.

The more widespread and persistent fogs accompany weak cyclonic movements, and their cause is similar to that of low-stratus clouds previously discussed. Moist air transported by light southerly winds converging upon east and northeast winds from a HIGH to the northeast brings the temperature and dew point together to produce fog and perhaps misting rain. Such widespread fogs prevailed over much of the Mississippi Valley and the Southeast from December 8 to 15, 1929, with high pressure to the north and east and an indefinite low-pressure area from the lower Mississippi Valley to the north Pacific coast.

The course of rivers is often marked by morning fogs; at Memphis it has been observed that after a warm period a shift of the wind to a northerly or westerly direction is likely to bring fog over the city from the river. A considerable number of the winter fogs at Memphis do not begin until after 7 a. m., according to A. R. Long, Weather Bureau official at Memphis.

Coastal or marine fogs are most frequent where there are large temperature differences between the land and the water; they are therefore much less frequent along the Gulf and south Atlantic coasts than in New England. "Differences between land and water temperatures,"

³ See MONTHLY WEATHER REVIEW Supplement No. 21, The preparation and significance of free-air pressure maps for the central and eastern United States, by C. L. Meisinger.

says Prof. H. C. Frankenfield, "are not so marked along the Atlantic and Gulf coasts as along the Great Lakes, and fogs forms with nearly equal temperatures when the latter do not differ sufficiently to cause complete condensation in the form of rain or snow. Frequently rain will be falling at one place on the coast while at the next station, only a short distance away, there will be dense fog. It is usually observed, however, that at the place where the rain is falling the wind velocity is greater than where the fog prevails and a decrease in the velocity would doubtless be at once followed by dense fog."

Frankenfield gives the following seasonal percentages of dense fog for the south Atlantic coast; Winter, 46; spring, 27; summer, 5; and autumn, 22. For the Gulf coast: Winter, 54; spring, 30; summer, 1; and autumn, 15.⁴ Along the Gulf coast the maximum frequency of fog is from the northwest coast of Florida to the northeast coast of Texas, the number of foggy days increasing toward the west. The greatest frequency is in January; scarcely any occur from June to September.

Weather conditions are described as very favorable for aviation in Florida by A. W. Brooks, Weather Bureau official at Miami Airport, who states that during the first year of operations, air mail failed to leave Miami on schedule only once—September 28, 1929—when a hurricane was passing through the Florida Straits into the Gulf of Mexico. Dense fogs are rare in southern Florida and are mostly shallow ground fogs which quickly disappear after sunrise. A solid overcast of low stratus or nimbus clouds is rare in southern Florida, Brooks states, except during a passing shower or when a hurricane is in the vicinity.

CENTRAL STATES

By VINCENT JAKL

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The portion of the country considered in this section comprises those States or portions of States lying between about the eighty-eighth and one hundred and fifth meridians, and extending from the Canadian boundary to the southern limits of the country, but not including the immediate Gulf coast.

Over this area, in common with other portions of the country, the average conditions of ceiling and visibility can be judged to a fair degree of accuracy by the general average amounts of precipitation. Ceiling and visibility are both controlled in large measure by the amount of moisture—both visible and invisible—contained in the air, while the moisture element is in turn roughly proportional to the average frequency and intensity of precipitation. We therefore find that there is a progressive improvement with respect to these conditions from east to west, slow at first, and then more rapid westward from about the ninety-eighth meridian, as the more arid regions of the plains States are approached.

As regards visibility, another contributing factor to this graduation of average conditions from east to west is the general lessening in the amount of smoke from cities and industrial regions, parallel to the diminishing density of population westward. There is also an appreciable improvement in average visibility from north to south, this latitudinal difference being, however, confined to the colder months. As may be inferred, the Southern States enjoy a relative infrequency of snowfalls, as compared with Northern States, and snowfall, as is well known, diminishes visibility much more than rainfall. Moreover,

the more pronounced changes in temperature and the precipitation that frequently attends such changes, which Northern States are subject to, are conducive to greater frequencies in light to moderate fogs. Dense fogs are brought about by special conditions, therefore we find that there is no important variation in this element with latitude, but a noticeable variation with longitude; that is, greater frequency in dense fogs over eastern than over western sections on the average. The more general use of natural gas for heating in the Southern States is perhaps not a negligible factor in bettering the conditions of visibility there as compared with Northern States.

The advantage that the Southern States enjoy is not really as great as might be apparent from the foregoing, as the favorable conditions mentioned are partly offset by low-pressure areas that first become evident as such in the Southwest and pass northeastward. These southwestern Lows develop with northeastward progress, and cause widespread precipitation attended by low clouds and poor visibility. In their pronounced form they are peculiar to the colder months, and affect the middle and much of the southern portions of this area.

The western portions of the area likewise are affected by a condition peculiar to them that modifies the general statement that visibility always improves westward. These are the dust and sand storms that affect the arid regions, more particularly those of the Southwest, and are most likely to occur in spring when the surface winds are on the average the strongest. The diminished visibility resulting from these storms is a factor to be reckoned with; nevertheless it is of far less importance than the products of moisture that are the chief cause of poor visibility over eastern sections.

A fair indication of relative weather conditions may be had from a comparison of the number of cloudy days over different portions. A cloudy day is one on which the average cloudiness was equal to eight-tenths or more of an overcast sky. Over Minnesota and Wisconsin the average annual number is 130 to 150, while over the western Dakotas it is 80 to 100, and in the Plains region of Wyoming and Colorado, 60 to 70. In Iowa and eastern Nebraska, it is about 100, in Illinois and eastern Missouri and Arkansas, 110 to 120, while in northern and western Texas, from 30 to 50.

Over all the area low clouds are much more frequent and more prolonged in winter than in summer. Those in summer are largely in connection with thunderstorms, which are usually of short duration as compared with the overcast rainy or snowy conditions of winter. In winter, clouds that are low enough to be a hindrance to flying are usually associated with fogs, mists, snows, and other forms of low visibility.

The distinction must be made between the number of days on which unfavorable conditions of ceiling and visibility are recorded as occurring sometime during the day, and the number of days that they are persistent throughout the day, as in the former case a flight may merely be delayed, while in the latter it may have to be canceled for the day. The relation of the former to the latter is at least 2 to 1. The proportion is smaller in winter than in summer; that is, a poor condition is more likely to persist throughout the day in winter than in summer; it is also more likely to persist throughout the day over eastern sections of the district than over western sections.

In any generalization such as this, exception must be made of local peculiarities. For example, river valleys are more susceptible to radiation fogs than surrounding

⁴ Weather Forecasting in the United States, Chap. IX.